That the test is somewhat delicate may be inferred from the fact that I have obtained it in a number of diabetic urines with a levorotation after fermentation of 0.2 and a ferric chloride reaction much weaker than that given by any of the above urines in which the oxybutyric acid was quantitatively determined. It has been my experience that the amount of β-oxybutyric acid varies directly (although not necessarily proportionately) with the amount of diacetic acid present and that the ferric chloride reaction varies directly in intensity with the amount of diacetic acid present.[15]

In a number of normal urines tested the reaction has not been obtained. It was also absent in a number of urines showing a weak ferric chloride reaction.

THE EFFECT OF CERTAIN SO-CALLED MILK MODIFIERS ON THE GASTRIC DIGESTION OF INFANTS.

By T. Wood Clarke, M.D.,
FELLOW OF THE ROCKEFELLER INSTITUTE FOR MEDICAL RESEARCH, NEW YORK.

(From the Wards of the Babies' Hospital, New York, and the Chemical Laboratory of the Rockefeller Institute for Medical Research, New York.)

In the fall of 1907, at the instigation of Dr. L. Emmett Holt, investigations were undertaken at the Rockefeller Institute in New York, in the hope of throwing light on some of the as yet obscure questions of infant digestion. The problem to be attacked was that of the digestion of milk in the infant's stomach, and more particularly the exact action of the more commonly used, so-called "milk modifiers," and their influence upon digestion both in health and disease.

A review of the literature of the gastric digestion of the infant[1] shows much valuable work on its physiology and its variations according to age and health. It has been shown that all the physiological factors occurring in the adult stomach are present in the infant, but in weaker form. It has further been proved that the younger the infant, the more active the motility of the stomach, that this motility is greater with woman's milk than with artificial food, and in health than in disease. It has been proved that the acidity of the gastric contents increases regularly after a meal for some time, but that free hydrochloric acid cannot be demonstrated for an hour or more after the ingestion of the food. This phenomenon has been shown to be due not to a lack of secretion of hydrochloric acid during the early stages of digestion, but to the striking power which casein has to combine with or adsorb it. Heubner has found that to 100 c.c. of cow's milk could be added 0.324 gram of hydrochloric acid before any test for the free acid could be obtained. Woman's milk will take up about one-half of that amount. It has further been proved that it is that hydrochloric acid which is combined with the protein which acts in peptic digestion, and that only, while the occurrence of free hydrochloric acid is merely a sign that more of the acid is present than is required for complete digestion of the protein. Opinions differ as to the occurrence of lactic and volatile fatty acids in the child's stomach, while the presence of a fat-splitting enzyme has been both asserted and denied. Pepsin is always found in the infant stomach in both health and disease, and gastric digestion goes on to the formation of small amounts of peptones but no amino-acids. Rennin is always present after the first few weeks of life. Whether before that, or not, is a moot question.

---

[15] Archives of Internal Medicine, February, 1908.

[1] Amer. Jour. Med. Sci., 1909, cxxxvii, 674.

For many years the medical profession has been adding barley water and lime water to cows' milk to increase its digestibility, and in more recent years sodium citrate and malt extract have been used extensively. There are many physicians who believe that each of these substances is at times of value in infant feeding, and each probably has his own rules by which he determines which is indicated in a particular case. Such knowledge, however, is largely empirical, as we have but little idea, or, at least, proof of what these substances do in the stomach and what the chemistry of their action really is. With the exception of some work of Einhorn twenty years ago, in which he investigated the motility and acidity of the gastric contents after feeding woman's milk, cow's milk and water, cow's milk and barley water, and several artificial foods, practically nothing has been done along these lines.

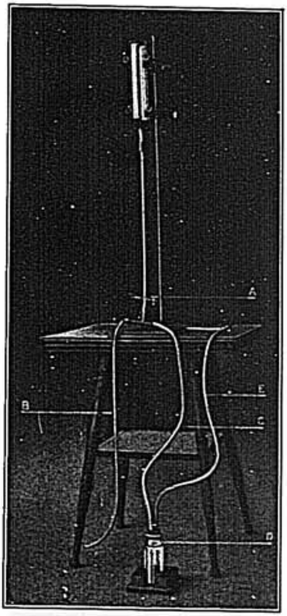
In these investigations, it was considered advisable first to use normal infants. This, however, not being practical, owing to the difficulty of obtaining such in a hospital, children who approached as nearly as possible a normal state of health were selected. All were patients at the Babies' Hospital in New York, and none were suffering from obvious digestion disturbances at the time of the examination. To obviate, as far as possible, the error due to individual variations it was attempted to take each case through a complete series of comparative examinations. In all 122 observations were made on 24 such infants, varying from two to eight months of age.

The test feedings given were of three series, designated Series I, II, and III. The purpose of Series I was to investigate the effect of the substances employed upon gastric secretion and for this purpose they were given with water alone. The three test feedings of this series consisted of a 5 per cent. solution of milk sugar—as an inert substance—barley water, and a 5 per cent. solution of lime water. In Series II, the substance was added to a mixture of cow's milk and water, equal parts. In this series was included woman's milk undiluted. It therefore embraced woman's milk, cow's milk and water, cow's milk and barley water, equal parts, cow's milk and water with 5 per cent. lime water, and cow's milk and water with 1 grain of sodium citrate to the ounce.. In Series III, experiments were made with cow's milk in the dilution of one part in four, and lime water, barley water and sodium citrate were investigated. In nearly all the cases, the test feeding was given the first thing in the morning, six to eight hours after the preceding nourishment. In a few only was the stomach washed a half-hour before the feeding. Owing to the various times which the child took in ingesting the meal, it was deemed more reliable to take the time from the minute at which the feeding was finished rather than from that of its beginning. This was done in every case.

On account of the difficulty sometimes encountered in removing the stomach contents of young infants by the ordinary method of stomach tube and funnel, and the necessity of working as rapiddly as possible, a special apparatus was constructed for this purpose (see illustration). This consists of a graduated glass reservoir holding 500 c.c. of water, attached by a clamp to an iron upright so that it stands about two feet above the table. From the outlet, two to three feet of soft rubber tubing leads to a T-tube of large caliber. Just above the T-tube is a pinch cock (*a*). Over one arm of the T-tube is drawn the stomach tube, a soft rectal tube either 22 or 23 French (*b*). From the second arm of the T-tube runs a stiff tubing (*c*) to a bottle on the floor (*d*). The bottle fits into a wooden stand to keep it in an upright position and is supplied with a tightly fitting rubber stopper, through which protrude two glass tubes. The tubing (*c*) from the T-tube fits tightly over one, while from the second extends about four feet of similar stiff tubing (*e*). This last is held in the mouth of the operator and is used to apply gentle suction when for any reason the stomach contents do not siphon quickly. The bottle is detachable and is used as a specimen bottle.

In the investigation under consideration, the contents were removed without washing. The rubber stopper was then transferred to a second specimen bottle and, when desired, the stomach washed by alternately opening and closing the pinch cock at the same time with the fingers pinching and opening the tube (*c*) from the T-tube to the specimen bottles. This wash water was not used for investigation, and the lavage was performed merely to make it certain that most of the stomach contents had been obtained, or for therapeutic purposes. It was surprising to see how large a stomach tube a young infant could be made to swallow if held in an upright position in the nurse's arms, if no attempt was made to pass the pharynx until the child took a deep inspiration. The tube was passed with great ease and apparently with a minimum of discomfort. Most of the children, after having overcome the initial fright, and having become slightly used to the procedure, made very little effort to cry and some seemed quite content to suck on the tube. Though some of the babies failed to gain weight during the period of investigation—possibly due to the frequent changes in the foods used—no serious or injurious results followed the procedure.

The specimens were taken at once to the chemical laboratories of the Rockefeller Institute and under the supervision of Dr. P. A. Levene, submitted to the following examinations: The quantity was carefully measured in order that by this means a rough estimate of the gastric motility might be obtained (A)[2]. The inaccuracy of drawing exact conclusions owing to the varying consistency of the milk curd and the uncertainty of complete evacuation is thoroughly appreciated. The acidity was estimated by titration with $\frac{n}{10}$ NaOH,



Apparatus used to evacuate the stomach. (For description see the text.)

---

[2] Letters in parentheses refer to the columns in the tables in which the results are recorded.

phenol-phthalein as an indicator (B). The hydrochloric acid in a free state was tested qualitatively with Congo red paper and quantitatively by titration against dimethylamidoazobenzol. The specimen used for the estimation of acidity, usually 5 c.c., after being neutralized was transferred to a platinum dish and evaporated over the steam bath to dryness. It was then carefully carbonized over a free flame, and the residue washed into a porcelain dish. In this, the chlorides were estimated by the method of Volhard. This result was calculated as parts per mille and recorded as "total chlorides" (C). A second portion of the contents was evaporated without the addition of NaOH, carbonized, and the chlorides estimated by the same method. This constituted the inorganic or fixed chlorides (D). The difference between the total chlorides and the sum of the fixed chlorides and free hydrochloric acid, shows the amount of chlorides which have gone into chemical combination with the milk proteins and are recorded as "organically bound chlorides" (E). It is this last item which is of importance in estimating the digestive capacity of various stomach contents when proteins are in the stomach. It has been shown by various authors that it is the combined chlorides only which act in peptic digestion, and that free hydrochloric acid in the stomach is merely a sign that more acid has been secreted than is required for complete digestion. The inorganic or fixed chlorides are, of course, inert. Acidity, fixed chlorides, and total chlorides will vary markedly with the food taken into the stomach, whereas the combined chlorides designate the exact amount which is being put to practical use. Tests were made in a number of cases for lactic acid, but as it was found in no case examined the proceeding was discontinued.

The method of estimating the digestive power of the gastric contents varied according to whether there were protein substances in the test meal or not. In Series I in which the "modifier" was given in water, without milk, the method was as follows: To each of the three portions of 5 c.c. of the contents was added 2 c.c. of fresh cow's milk. Portion A was untreated. To portion B was added $\frac{n}{10}$ HCl until the casein had become saturated with the acid, as shown by the test for free acid with Congo red paper. Portion C was boiled before the milk was added, and then acidified in the same way as D. To each portion was added 1 c.c. of toluol. For A and B 25 c.c. measuring flasks were used; C requiring boiling, was placed in a small Erlenmeyer flask. All these portions were then placed in the incubator at body temperature for twenty-four hours. At the end of this time C was washed into a 25 c.c. measuring flask, by means of a saturated solution of zinc sulphate in five per cent. H_2SO_4. Enough solid zinc sulphate was added to each flask to saturate the solution, and the contents then raised in volume to 25 c.c. by adding the saturated zinc sulphate solution. The flasks were then placed in the ice box for twenty-four hours more.

This latter proceeding was to insure a constant temperature at which the coagulation took place regardless of the season. At the end of the twenty-four hours the specimens were filtered through folded filter papers. The amount of N in 10 c.c. of the filtrate was determined by the Kjeldahl process. The amount of nitrogen calculated for the 25 c.c. is designated as "peptone nitrogen." The amount of N in the filtrate of portion C (I) that portion which was boiled previous to the addition of the milk shows the amount of peptone and residual N in the given amount of contents and milk, and is used as a control, the amount being subtracted from the amount of N in the filtrates of A and B.

The amount of N, theretore, in the filtrate of A after the deduction of C gives the absolute amount of N in the form of peptones which were produced by the action of 5 c.c. of the stomach contents upon 2 c.c. of milk in twenty-four hours (J), whereas the N in the filtrate of B, similarly corrected by the deduction of C, gives the amount of peptone formation in twenty-four hours when the amount of acid is practically the same in all cases—in other words, an estimate of the amount, or at least actively, of the pepsin itself (K).

In Series II and III in which milk was given in the test meal the procedure was somewhat different. The contents were thoroughly mixed and then three equal parts measured out: when possible 15 c.c. in each part, when lack of material prevented, 10 c.c. One portion A was saturated at once with $ZnSO_4$ and the volume raised to 25 c.c. by the saturated $ZnSO_4$ solution. The second portion B was placed in the incubator with toluol for twenty-four hours and then saturated with $ZnSO_4$, while the third portion C was acidified with $\frac{n}{10}$ HCl until the free acid showed a reaction to Congo paper, and then treated in the same manner as B. All three portions on being saturated with $ZnSO_4$ were placed in the ice box for twenty-four hours and then treated in a similar manner to the specimen in Series I. The amount of N in the filtrate of portion A represents the peptones and residual N in the stomach at the end of an hour (G). This is, however, but a very rough estimate of the gastric digestion which has taken place, as it is open to variations due to the amount of peptone in the food and to the much greater variation dependent upon absorbtion and motility. The difference, however, between the amount of peptone at the end of the hour and that of the twenty-four hours more in the thermostat, while not designating the digestion which has taken place, in the stomach may be used as an indication of the digestive power of the gastric juice at the time of its removal and is designated as "increase in peptone nitrogen" (J). The difference between the peptone N of C and A by eliminating variations in acidity similarly estimates the activity of the pepsin in the stomach at the end of the hour (K).

Lastly to each of three small test tubes was added 1 c.c. of gastric contents, in Series I unfiltered, in Series II and III filtered. Tube

I was untreated (L); II was acidfied with HCl until it showed bright red with dimethylamidoazobenzol (M); and III was boiled and acidfied (N). The digestive power of these were then tested by the method of Mette, the digestion being estimated after twenty-four hours at body temperature.

These results were of use not only to confirm the previous findings but to show the presence or absence of "free pepsin," that is, pepsin not combined with the protein. The absence in every case of albumen digestion in the specimen which had been boiled and acidfied (N) precluded the action of the acid in causing the digestion while the addition of toluol precluded bacteria.

Specimens of the test feedings as given to the patient were also examined for peptone N (Q), and total chlorides (P).

Results. The results of these investigations are incorporated in tables of averages.

Table I.—*Normal infants. Investigation of lactose, lime water, and barley water administered in water, without milk. The specimen was removed from the stomach thirty minutes after the end of the feeding.*

	Number of cases	Amount of material removed from stomach c.c. A	Total acidity ‰ B	Total chlorides ‰ C	Fixed chlorides ‰ D	Free hydrochloric acid ‰ F	Peptone nitrogen after 24 hours in the thermostat; untreated contents mgr. G	Peptone nitrogen after 24 hours in the thermostat; acidified contents mgr. H	Peptone nitrogen after 24 hours in the thermostat; boiled contents mgr. I	Increase of peptone nitrogen; untreated contents mgr. J	Increase of peptone nitrogen; acidified contents mgr. K	Mette's tube tests; untreated contents mm. L	Mette's tube tests; acidified contents mm. M	Mette's tube tests; boiled contents mm. N
5% lactose solution	11	37	0.23	0.40	0.24	0.16	2.3	4.3	1.5	0.8	3.8	0.32	2.79	0
Lime water, 5 parts water, 95 parts	15	36	0.31	0.61	0.41	0.20	3.1	4.6	1.2	1.9	3.4	1.07	3.46	0
Barley water	12	50	0.34	0.82	0.69	0.13	2.6	5.4	1.3	1.3	4.1	0.35	3.00	0

Healthy Infants. Examining first Series I (Table I), in which the substance to be investigated was given with water only, the following facts will be noted: Using the sugar and water as a control, it is seen (A) that the amount of material obtained was smallest after sugar and water and lime-water, and larger after barley water. The total acidity (B) is higher after both lime water and barley water than after a plain milk sugar solution; the total chlorides (C) are higher after lime water than after sugar and highest of all after barley water; while the fixed or inorganic chlorides (D) vary in about the same ratio, leaving, however, most free HCl (F) after lime water and least after barley water. From these results, it would appear that any increase in chlorides following the administration of barley water is due to the extra salt given in the food, while when the lime water is used, an absolute increase of hydrochloric acid secretion results.

Examining now the digestive power of the gastric juice, it will be seen (J) that 5 c.c. of the stomach contents was able to produce in twenty-four hours from 2 c.c. of cow's milk very little peptone after sugar, more after barley water, and most after lime water, while the next column, that in which the acidity was equalized to demonstrate the relative amount of pepsin (K), the variations are much less in proportion, but show, if anything, the greatest amount of pepsin after barley water. The Mette's tube experiment, when unacidified (L), confirms the relative digestive powers of the different contents (J), while the next column (M), the Mette's tube acidified, tends to show again that the amount of pepsin varies but slightly.

In Series II (Table II), that in which woman's milk undiluted and equal parts of milk and water were given in the test feeding, the amount obtained (A) after feeding woman's milk is distinctly higher than after the other feedings, which here include sodium citrate, one grain to the ounce. The total acidity (B) is practically the same in all cases though somewhat higher after each of the three "modifiers" than after the plain milk. The total chlorides (C) are again higher after barley water and lime water, but slightly lower after sodium citrate than after the plain milk. A marked variation appears in the fixed chlorides (D). Taking the milk and water as a standard, the fixed chlorides, after a feeding including lime water, barley water, and sodium citrate are distinctly raised. The increase after barley water is again explainable by the larger amount in the food (P), the other three feedings showing practically the same salt contents. The low total chlorides and fixed chlorides after woman's milk are also explicable from the smaller amount found in the food. There being in no case free HCl (F) found in these rich milk diets, the difference between the total and fixed chlorides was the active organically bound chlorides (E). This shows that, though after lime water a certain amount of the hydrochloric acid was converted into calcium chloride and rendered inert, nevertheless a sufficient excess of the acid was secreted to raise that organically combined with the casein to the normal and to fulfill the demands of digestion. After barley water, though the excess of chlorides was due in a large part to that given in the food, a slight increase of combined chlorides is shown. After sodium citrate, the sodium bound the greater part of the HCl, while no stimulation to a further increase was offered, thus leaving a minimum of acid to act in digestion.

TABLE II.—*Normal infants. Investigation of woman's milk and of lactose, barley water, and sodium citrate administered in equal parts of cow's milk and water. Time in stomach, sixty minutes after the end of the feeding.*

	Number of cases	Amount of material removed from stomach	Total acidity	Total chlorides	Fixed chlorides	Organically bound chlorides	Free hydrochloric acid	"Peptone nitrogen" immediately	"Peptone nitrogen" after 24 hours in the thermostat; untreated specimen	"Peptone nitrogen" after 24 hours in the thermostat; acidified specimen	Increase in peptone nitrogen; untreated specimen	Increase in peptone nitrogen; acidified specimen	Mette's tube tests; untreated contents	Mette's tube tests; acidified contents	Mette's tube tests; boiled contents	Chlorides in the food	"Peptone nitrogen" in the food
		c.c.	‰	‰	‰	‰	‰	mgr. per 100 c.c.	mgr. per 100 c.c.	mgr. per 100 c.c.	mgr. per 100 c.c.	mgr. per 100 c.c.	mm.	mm.	mm.	‰	mgr. per 100 c.c.
		A	B	C	D	E	F	G	H	I	J	K	L	M	N	P	Q
Woman's milk, undiluted	5	100	0.97	0.88	0.37	0.51	0.00	53	81	104	28	51	0	1.08	0	0.20	41
Cow's milk and water, *dd*	13	52	0.84	1.12	0.72	0.39	0.01	27	68	98	41	71	0	2.30	0	0.40	16
Cow's milk and barley water, *dd*; 5% lime water	9	55	1.03	1.22	0.81	0.41	0.00	33	73	84	40	51	0	2.70	0	0.35	16
Cow's milk and barley water, *dd*	11	53	1.01	1.49	0.96	0.53	0.00	32	81	98	40	60	0	1.59	0	0.75	14
Cow's milk and water, *dd*; sodium citrate, 0.2%	8	55	1.03	0.98	0.89	0.09	0.00	25	65	86	40	61	0	2.40	0	0.41	13

A study of the amount of peptone N found in the stomach at the end of the hour (G) shows, with the exception of woman's milk, whose high content is due to the large amount of residual nitrogen in the food (Q), approximately similar results, with the lime water slightly the highest, and sodium citrate a shade low. The increase of peptone N during twenty-four hours in the incubator (J) shows that the digestive power following milk and water, lime water, barley water, and sodium citrate is about equal. The increase of peptone N after acidification with HCl and twenty-four hours in the thermostat (K) shows practically similar amounts of pepsin following cow's milk and water and cow's milk and barley water, whereas after sodium citrate and lime water it is a trace lower. This low figure after lime water is difficult to explain as it is at variance with all the other results. The amount of free pepsin, as shown by the Mette's tubes, is practically the same in all except woman's milk and barley water, which are low.

TABLE III.—*Normal cases. Investigation of lactose, barley water, and sodium citrate, administered in cow's milk, 1 part, water, 3 parts. Time in the stomach, sixty minutes after the end of the feeding.*

	Number of cases	Amount of material removed from stomach	Total acidity	Total chlorides	Fixed chlorides	Organically bound chlorides	Free hydrochloric acid	Mette's tube tests; untreated contents	Mette's tube tests; acidified contents	Mette's tube tests; boiled contents
		c.c. A	‰ B	‰ C	‰ D	‰ E	‰ F	mm. L	mm. M	mm. N
Cow's milk, 25% in water	7	36	0.75	1.33	0.64	0.65	0.04	0	2.66	0
Cow's milk, 25% in water, 5% lime water	7	30	0.97	1.27	0.60	0.64	0.03	0	2.50	0
Cow's milk, 25% in barley water	8	23	1.13	1.67	0.84	0.70	0.13	0	2.86	0
Cow's milk, 25% in water, sodium citrate, 0.2%	5	21	0.71	1.09	0.92	0.18	0.00	0	2.55	0

The third series of experiments as shown in Table III, that in which the substances under investigation were given with one part of milk in four, tend partially to confirm the findings of Series I and II. Lime water and barley water increase the total acidity (B), while the amount of free HCl (F) is too minute for consideration, though it should be noted that sodium citrate is the only substance used in this series, after which no free HCl was demonstrated in the gastric contents. The total chlorides (C) are highest after barley water and lowest after sodium citrate, while the fixed chlorides are highest after sodium citrate, leaving again an equality of combined chlorides (E) after milk and water and lime water and barley, with a great decrease after sodium citrate. The figures demonstrating peptic digestion in this series are not very trustworthy, as the small amount of stomach contents usually obtained precluded thorough investigation of this point, and they are therefore omitted.

It would be inadvisable to attempt to draw definite conclusions from these series of experiments owing to the well known fallacies of averages in physiological work. A few facts, however, seem to be sufficiently suggestive to warrant their mention. It would appear, from the fact that in every case the addition of acid to the contents caused a greater increase of peptone formation than in the specimens in which the acid was not used, that when a deficiency of protein digestive power exists, it is due to a lack of acid rather than any want of pepsin. There is always more than enough pepsin in proportion to the amount of acid. As to the effects of the various substances investigated, it would appear that barley water has but slight, if any, effect upon HCl secretions. Lime water although usually given with the idea of reducing the acidity of the stomach may have quite the opposite result. Though a portion of the HCl found in the stomach is neutralized by the lime, the alkali stimulates to an increased secretion of HCl which may raise the acidity even higher than that obtained with milk alone. Sodium citrate, on the other hand, would appear to act in quite the opposite manner for, though preventing coarse curds, it converts most of the HCl into sodium chloride, liberating citric acid—a substance considered of little value in digestion—and does not stimulate further secretion of HCl. It would thus appear to weaken the protein digestive power of the gastric juice by using up its hydrochloric acid.

Pathological Cases. Having learned these facts concerning the physiology of the infant stomach and the effect of lime water, barley water, and sodium citrate upon the gastric secretion in health, it seemed advisable to undertake investigations upon cases suffering from digestive and nutritional disorders, in order to learn to what extent their gastric secretion varied from the normal and if possible to ascertain whether these various substances acted upon the diseased stomach in the same manner as upon the healthy organ. For this purpose two classes of cases were examined—marasmus cases without vomiting, and persistent chronic vomiting cases. Of the first class 14 cases were studied and 35 examinations were made, while of the chronic vomiting cases, 10 infants were used and 30 meals extracted. In these cases the test feeding given consisted of lactose, barley water, or lime water, given in water only, in the same concentration as was used with the healthy infants.

TABLE IV.—*Marasmus cases. Investigation of lactose, lime water, and barley water, administered in water without milk. Time in the stomach, thirty minutes after the end of the feeding.*

	Number of cases	Amount of material removed from stomach c.c. A	Total acidity ‰ B	Total chlorides ‰ C	Fixed chlorides ‰ D	Free hydrochloric acid ‰ F	"Peptone nitrogen" after 24 hours in the thermostat; untreated contents mgr. G	"Peptone nitrogen" after 24 hours in the thermostat; acidified contents mgr. H	"Peptone nitrogen" after 24 hours in the thermostat; boiled contents mgr. I	Increase of peptone nitrogen; untreated contents mgr. J	Increase of peptone nitrogen; acidified contents mgr. K	Mette's tube tests; untreated contents mm. L	Mette's tube tests; acidified contents mm. M	Mette's tube tests; boiled contents mm. N
5% lactose solution	14	20	0.28	0.34	0.21	0.13	3.5	5.7	1.6	1.9	4.1	0.22	3.62	0
Lime water, 5 parts; water, 95 parts	9	25	0.33	0.50	0.32	0.21	3.2	4.4	1.9	1.6	2.5	1.16	3.22	0
Barley water	8	30	0.40	1.46	1.19	0.20	3.4	5.0	1.7	1.7	3.3	1.33	3.84	0

TABLE V. (*Compiled from Tables I, IV, and VI*).—*Table showing the differences between the gastric contents of the various classes of infants studied. The test feedings consisting of a 5% solution of lactose in water. The stomach contents were removed thirty menutes after the end of the feeding.*

	Number of cases	Amount of material removed from stomach c.c. A	Total acidity ‰ B	Total chlorides ‰ C	Fixed chlorides ‰ D	Free hydrochloric acid ‰ F	"Peptone nitrogen" after 24 hours in the thermostat; untreated contents mgr. G	"Peptone nitrogen" after 24 hours in the thermostat; acidified contents mgr. H	"Peptone nitrogen" after 24 hours in the thermostat; boiled contents mgr. I	Increase of peptone nitrogen; untreated contents mgr. J	Increase of peptone nitrogen; acidified contents mgr. K	Mette's tube tests; untreated contents mm. L	Mette's tube tests; acidified contents mm. M	Mette's tube tests; boiled contents mm. N
Normal cases . .	11	37	0.23	0.40	0.24	0.16	2.3	4.3	1.5	0.8	3.8	0.32	2.79	0
Marasmus cases . .	14	20	0.28	0.34	0.21	0.13	3.5	5.7	1.6	1.9	4.1	0.22	3.62	0
Hypoacidity vomiting cases	4	40	0.15	0.19	0.09	0.08	2.3	3.9	1.7	0.6	2.2	0.08	3.50	0
Hyperacidity vomiting cases	6	28	0.44	0.52	0.20	0.33	4.5	6.9	2.1	2.4	4.8	1.61	4.55	0

The marasmus cases (Table IV) show very slight variation from the normal infants (Table V). The amount of material obtained (the stomach was here evacuated thirty minutes after the child had finished its feeding) was slightly less than in the normal, whereas the total acidity and free HCl were practically equal in the two series. The increase chloride secretion following the administration of lime water shows quite as well in these cases as in the healthy children. It is of interest to note that the peptic activity in these cases is not reduced, appearing to be even a little greater than in the normal infants.

TABLE VI.—*Chronic vomiting cases. Investigation of the gastric contents in the two classes of this condition, and the effect of lactose, lime water, and barley water upon them. Time in stomach, thirty minutes after the end of the feeding*

	Number of cases	Amount of material removed from stomach	Total acidity	Total chlorides	Fixed chlorides	Free hydrochloric acid	"Peptone nitrogen" after 24 hours in the thermostat; untreated contents	"Peptone nitrogen" after 24 hours in thermostat; acidified contents	"Peptone nitrogen" after 24 hours in the thermostat; boiled contents	Increase of peptone nitrogen; untreated contents	Increase of peptone nitrogen; acidified contents	Mette's tube tests; untreated contents	Mette's tube tests; acidified contents	Mette's tube tests; boiled contents
Hypoacidity cases		c.c. A	‰ B	‰ C	‰ D	‰ F	mgr. G	mgr. H	mgr. I	mgr. J	mgr. K	mm. L	mm. M	mm. N
5% lactose solution	4	40	0.15	0.10	0.09	0.08	2.3	3.9	1.7	0.6	2.2	0.08	3.50	0
5% lime water solution	3	34	0.06	0.40	0.37	0.01	1.6	3.8	1.2	0.4	2.6	0.00	3.20	0
Barley water	2	33	0.27	0.55	0.42	0.06	3.5	4.3	1.9	1.6	2.4	0.00	4.42	0
Hyperacidity cases														
5% lactose solution	6	28	0.44	0.52	0.20	0.33	4.5	6.9	2.1	2.4	4.8	1.61	4.55	0
5% lime water solution	6	23	0.39	0.60	0.30	0.31	3.2	4.4	1.7	1.5	2.7	1.05	3.52	0
Barley water	4	38	0.39	0.77	0.54	0.21	3.2	4.2	2.1	1.1	2.1	0.59	3.58	0

In the *chronic vomiting cases* (Table VI), of which ten were studied, it was early seen that they naturally fell into two classes. In four of them the acid contents was distinctly subnormal and in the other six it was exceptionally high. In the *hypoacidity vomiting cases* the total acidity (B) was very slight and free HCl (F) either absent or present only in minute traces. These cases responded slightly to the administration of lime water, as is shown by the higher total chloride content of the stomach, but not sufficiently to neutralize the lime, and the free HCl was present in a trace only in one case. The peptone-forming power of the untreated stomach contents was somewhat low, while the action on the Mette's tubes was practically nil (L). That the failure of digestive power was due to a lack of acid, and not to any deficiency of pepsin is shown by the strong action in the Mette's tubes after acidification of the specimens (M).

In the *hyperacidity vomiting cases* (Table VI) the total acidity (B) and free HCl (F) were distinctly high after all the test diets, the total chlorides and fixed chlorides varying in the same ratio as in the normal. The peptone formation from milk was also distinctly above normal (J) as was the Mette's tube estimations. The lack of an increase of digestive power of the acidified specimen, with the single exception of the milk sugar specimens, shows that this increase of proteolysis is again due to an increased acidity and not to any increase of pepsin.

Finally to learn whether these effects of the salts used in infant feeding occurred in all cases, a short series of experiments were made in which 18 unselected infants, the entire content of a ward, were examined for the acidity and chlorides (Table VII). In these cases the test feeding consisted of two parts of cow's milk and one part of water, and the substances used were lime water, 5 per cent., sodium citrate 0.2 per cent., and potassium carbonate 0.1 per cent., with sufficient lactose to make the carbohydrates 6 per cent. The meals were extracted one hour after the child received the bottle, in this respect differing from the other experiments. In this series the effect of lime water shown in the other experiments is not evident, but that of sodium citrate is fully confirmed by the increase of the fixed chlorides and consequent reduction in the organically combined chlorine. The potassium carbonate also increased the fixed chlorides and reduced the organic chlorine, but not so markedly as did the citrate. There was no increased stimulation of HCl by this salt.

TABLE VII.—*Unselected ill infants. Investigation of sodium citrate, lime water, and potassium carbonate administered in a mixture consisting of cow's milk, 1 part, water, 2 parts, and lactose sufficient to make* 6%. (1.40-6-1.30.)

	Number of cases	Amount of material removed from stomach	Total acidity	Total chlorides	Fixed chlorides	Organically bound chlorides	Free hydrochloric acid
		c.c. A	‰ B	‰ C	‰ D	‰ E	‰ F
Cow's milk and water . . .	18	46	0.85	0.98	0.29	0.69	0
Cow's milk and water; 5% lime water solution	17	51	0.78	0.94	0.24	0.68	0
Cows milk and water; sodium citrate 0.2%	13	44	0.85	0.91	0.65	0.26	0
Cow's milk and water; potassium carbonate 0.1%	15	52	0.64	0.97	0.44	0.52	0

Review of Results. While fully appreciating the danger of drawing definite conclusions from the results of physiological investigations when these results are based on averages of the findings, a review of the above tables would seem to suggest at least certain facts. The motility of the stomach appears to be in inverse proportion to the concentration of the milk in the solution. The greater the dilution the more rapidly the organ empties itself. Lime water itself appears not to act, as is generally accepted in practical pediatrics, by reducing the acidity of the child's stomach. While unquestionably neutralizing a portion of the hydrochloric acid, the alkali stimulates in a further secretion of gastric juice. This raises the amount available in the form of free acid or organically bound chlorine at least to the amount normally occurring when the lime water is not added, and may cause a distinct over-stimulation of the gastric glands sufficient to produce a slight relative hyperchlorhydria. The effect of barley water in the stomach appears, at least from the purely chemical viewpoint, to be very slight, neither stimulating nor retarding gastric secretion. The action of sodium citrate, however, is quite definite. It acts similarly to the alkalies in converting a large portion of the hydrochloric acid into sodium chloride, while at the same time it does not stimulate to a further secretion of acid. In this way it reduces decidedly the amount of hydrochloric acid in the stomach. How potent a factor this may be in the well known action of this salt in preventing the formation of curd in the infant stomach is an open question. It has been shown by several observers that in the young infant the amount of rennin is very slight and it is possible that most of the clotting is due rather to the action of the acid in the stomach than to the ferment.[3]

---

[3] That sodium citrate does act in inhibiting acid clotting is shown by the following simple experiment: Into each of eight Erlenmeyer flasks was placed 5 c.c. of fresh cow's milk and varying amounts of *n*/10 sodium citrate solution. After sufficient distilled water had been added to make the volume of fluid the same in all the flasks the solutions were titrated with *n*/10 HCl until clotting occurred. From the accompanying table it will be seen that each increase in the sodium citrate in the milk required a proportional increase of the HCl to produce the clot.

Flask	Cow's milk c.c.	*n*/10 sodium citrate added to milk c.c.	Distilled water added c.c.	Amount of *n*/10 HCl required for clotting c.c.	Increase in the quantity of HCl required for each increase of 1 c.c. sodium citrate c.c.
1	5	0	7	2.0	—
2	5	1	6	2.3	0.3
3	5	2	5	2.6	0.3
4	5	3	4	2.85	0.25
5	5	4	3	3.2	0.3
6	5	5	2	3.45	0.25
7	5	6	1	4.00	0.55
8	5	7	0	4.30	0.3

An examination of the individual cases treated with milk mixtures containing sodium citrate showed that in those cases in which the acidity of the stomach was low practically all the hydrochloric acid was converted into sodium chloride, while in those of high acidity

Protein digestion in the stomach of the young infant would appear to be very slight and such as does occur to be in fairly direct proportion to the amount of acid present.

PRACTICAL APPLICATION. A practical application of these results is suggested in connection with the class of infants who vomit persistently from birth. According to these results these cases, while showing no especial clinical differences, may be divided into two fairly definite groups according to the acidity of their gastric contents. If the hyperacidity found in the majority of these cases is the chief cause of their vomiting the fact of the excess of acid and its degree should be known in order that the treatment may have a rational basis. The administration and removal of a test feeding in a young infant is a simple procedure, the greatest difficulty being the finding of the most appropriate substance to be used. A simple five per cent. solution of lactose in water has shown the most striking differences between the acid content of the stomach of individual infants and appears to be the most suitable feeding to test the gastric contents. It might, however, be well to follow this test after a day by a second examination in which a mixture of cow's milk, one part to water two parts is used. By this means the stomach both in comparative rest and during active digestion may be studied and the amount of acid actually secreted, owing to the stimulation of the milk, determined. It seems probable that the results of such findings will give some important indication for treatment. When the acidity is low, a weak alkali to stimulate acid secretion or possibly a few drops of dilute hydrochloric acid will be indicated, whereas if an oversecretion of hydrochloric acid is found, either a higher protein meal, thereby binding more of the acid, or sodium citrate to convert the hydrochloric acid into sodium chloride may be found effective. The accurate knowledge of the degree of acidity may be of especial value in cases of congenital pyloric stenosis or pylorospasm. In the one case we have had the opportunity to examine, the gastric acidity was exceptionally high. This agrees with the findings of Knoepfelmacher, Engel, and others. If, as seems probable, the pylorospasm is due to the hyperacidity, an accurate knowledge of its degree must be of no little value in treatment.

SUMMARY. 1. The motility of the infant stomach varies inversely to the concentration of the food. The more dilute the food the more frequently may the feedings be given.

2. Lime water does not reduce the acidity of the gastric contents, the neutralizing of a portion of the acid being overcome by an

---

the amount of the fixed chlorides was increased by a fairly definite amount, namely 0.043 per cent. A calculation of the amount of hydrochloric acid which should theoretically combine with 0.2 per cent. sodium citrate shows that one would expect 0.061 per cent. Allowing for the increased dilution from the gastric juice it would seem that the 0.043 would approach rather nearly the theoretical amount and that, therefore, the combination of HCl with sodium citrate in the stomach closely follows chemical laws.

increased stimulation of hydrochloric acid by the gastric glands. This may even increase the amount of acid available for digestion.

3. Sodium citrate acts on the acid in the stomach converting it into sodium chloride and thus markedly reduces the "available hydrochloric acid."
4. Barley water seems to have no constant effect upon the chemistry of gastric digestion in the infant.
5. The type of infants who vomit persistently may be divided into two classes, hypoacidity and hyperacidity.
6. Test feedings should be given to this type of infants to determine to which class they belong.
7. A five per cent. milk sugar solution seems to be the most satisfactory feeding to determine fine differences in the gastric contents. This may be followed by a mixture of milk one part, water two parts, to determine to what extent the gastric glands are capable of responding to stimuli. For the lactose solution thirty minutes is the most satisfactory time to allow the feeding to remain in the stomach; for the milk mixture sixty minutes.
8. On purely theoretical grounds it would appear that when the acidity is low either small doses of alkalies or of hydrychloric acid are indicated while in hyperacidity sodium citrate holds out the best hope of benefit.
9. Protein digestion in the infant's stomach is slight and is proportional to the amount of hydrochloric acid in the organ.

I desire to express my thanks to Dr. L. Emmett Holt for the inspiration and the many valuable clinical suggestions given during the course of this work; to Dr. P. A. Levene for his aid in directing and overseeing the chemical side of the problem; and to Dr. Hemenway, resident physician, her assistants, and the nurses of the Babies' Hospital for their coöperation and kind assistance.

BOILS: A NOTE ON THEIR TREATMENT.[1]

By George Thomas Jackson, M.D.,
PROFESSOR OF DERMATOLOGY IN THE COLLEGE OF PHYSICIANS AND SURGEONS, COLUMBIA UNIVERSITY, NEW YORK.

Not long ago ringworm was regarded as a constitutional disease, and rules were given as to the general treatment of the patient in order to effect a cure. This ancient tradition still lingers, in so far as some doctors still insist that ringworm of the scalp is more obstinate in strumous than in other patients, and in them constitutional

---

[1] Read at a meeting of the Alumni Association of the City (Charity) Hospital, New York, January 13, 1909.